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COMPARING THE HYDRAULIC CONTROL OF TRACTOR THREE-POINT HITCH

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Abstract

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In this paper, there are monitored and compared the parameters of tractor three-point hitch control. Comparisons were carried out under laboratory conditions for two types of regulation. The first one was a standard mechanical and the second one was electro-hydraulic Bosch. Testing was performed on a test bench designed for the Department of Transport and Handling (Slovak University of Agriculture in Nitra). The results of measurements are evaluated statistically and shown in a graphical form.

Keywords: power control, mechanical hydraulic control, electro-hydraulic control

INTRODUCTION

During the testing, adjusting and controlling work of the agricultural machinery, we have proceeded in accordance with existing technical standards. The testing of agricultural tractors is no exception (Páltik *et al.,* 2007; Poničan, Korenko, 2008). The development of tractors and tools directed to system with either attached or trailed machines resulted in certain discrepancies between the manner of operation of tractors and the methods of measuring their tractive properties (Čupera *et al.*, 2011). Laboratory tests and verification of force effect in tractor's three point hitch were researched by many authors (Čupera *et al.*, 2010; Porteš *et al.*, 2013; Bentaher *et al.*, 2008; Kumar, 2012).

Position control – to every position of the operating lever (angle α) a certain position of the lifting arms respond (angle ϕ) and therefore also a certain position of the three-point hitch arms. This can be expressed by the relation

$$\phi = f(\alpha). \quad (1)$$

It means that the position control allows the adjustment to a required position (and therefore also to a working depth) of the mounted implement considering the tractor, and during operation the control mechanism retains the adjusted position. In case of a change of the adjusted position as a result of leakage in the lifting hydraulic cylinder, the control mechanism supplies refilling to the hydraulic cylinder with pressure oil and thereby adjusting to the original position of the three-point hitch.

Power control – to every position of the operating lever (angle α) a certain loading force F responds. This force operates in the lower draw bars of the three-point hitch (for tractors ZETOR UR II). The following relation is valid for power control:

$$F = f(\alpha). \quad (2)$$

It means that the power control retains the adjusted working resistance of the implement.

Mixed control – the position of lifting arms (angle ϕ) is given partly by the position of the operating lever (angle α) and partly by the value of loading force F. This can be expressed by the relation

$$\phi = f(\alpha, F). \quad (3)$$

Hydraulic devices have a wide application in powerful mechanisms of earth machines, road and construction machines, in agriculture and forest machines as well as in many other areas. Together with increasing demands on quality, these machines and devices increased demands on hydraulic components and systems, too (Tkáč *et al.*, 2007; Majdan *et al.*, 2013). The development of modern hydraulic components is aimed at an increase of transferred power, decrease of energy severity, minimization of environmental pollution, and increase of technical lifetime and machine reliability. It is very difficult to perform some tests directly on a machine (Tkáč *et al.*, 2008; Máchal *et al.*, 2013).

MATERIAL AND METHODS

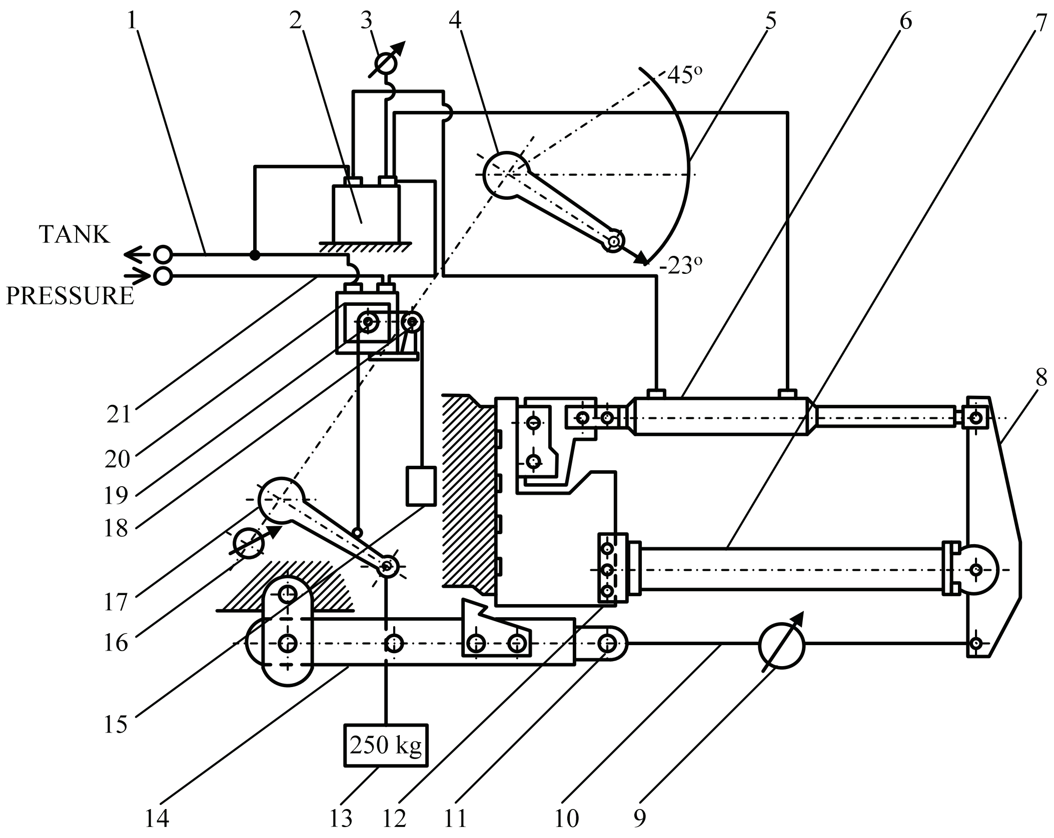
The laboratory comparison tests were done at the Department of Transport and Handling with a batch-produced mechanical hydraulic control of the Z-8011 and Z-16145 tractors and with electro-hydraulic control EHR 4 BOSCH built in the Z-16145 tractor. In consideration of the limited extent of the contribution below, only the laboratory tests of power control are presented. The goals of these tests were:

- depending on the position of the operating lever (angle α), to find out the value of loading force in the lower draw bars of the three-point hitch, i.e. function $F = f(\alpha)$;
- with respect to the position of the operating lever (angle α), to find out the static control deviation F from the nominal value of loading force, i.e. function $\Delta F = f(\alpha)$;
- under laboratory tests of power control, to perform the loading of the three-point hitch lower draw bars by a loading device with a simulator of loading;
- tests of power control to be performed with engaged feedback between the position of the three-point hitch and loading force at a 20% loading of the three-point hitch by lifting force and at an idle-running engine speed of 550 rpm.

Measured values:

- position of the operating lever (angle α),
- position of the lifting arms (angle ϕ),
- loading force F.

Laboratory tests were done by means of the loading device with the simulator (Fig. 1). The loading device comprised of a double-arm lever (8), which is hinged to a carrier tube (7) anchored on the upper hitch of the tractor (12). On the upper (longer) arm, there is attached



1: *Loading device with simulator*

the piston rod of the loading hydraulic cylinder (6). The loading hydraulic cylinder (6) is attached to the tractor's distributing box. On the lower (shorter) arm, there is affixed a dynamometer (9), which is at the second end attached through the draw bar (10) and by replacement ending (11) to the lower draw bars (14) of the three-point hitch.

The basic parts of the simulator are two parallel-connected flow control valves (2) and (20) of VSS-1 type. The left flow control valve (20) is through the chain (19) attached to the left lifting arm (17) of the three-point hitch. On the end of the chain, there is attached the reversing weight (15). Part of the simulator is an independent resource of pressure oil with a flow of 40 $dm^3.min^{-1}$ at pressure 16 MPa with a built-on pressure valve. The value of working pressure and also the value of loading force are adjusted by means of flow control valves (2) and (20). The presented method of engagement of the simulator together with the loading device allows the simulation of loading of the three-point hitch in laboratory conditions to examine the basic parameters of power control.

To measure the position of the operating lever, a precise potentiometer ARIPOT with a linear course was attached to the lever's shaft.

The other potentiometer (16) was attached to the lifting arms' shaft to measure the position of the three-point hitch. A mechanical protractor (5) was used to visually check the position of the three-point hitch. All measured values were continually recorded.

RESULTS AND DISCUSSION

The obtained results of laboratory tests of the standard hydraulics have shown that the power control is characterized rather by a high value of upper and lower static control deviations in the whole control range. It is visible from the results presented in Tab. I and graphed in Figs. 2 and 3. Each measurement of force and position control was permits 10 times under same condition. The measured tractors were in operation regime of using (approximately after 1,000 engine hours). Measured values present average values of 10 times replay.

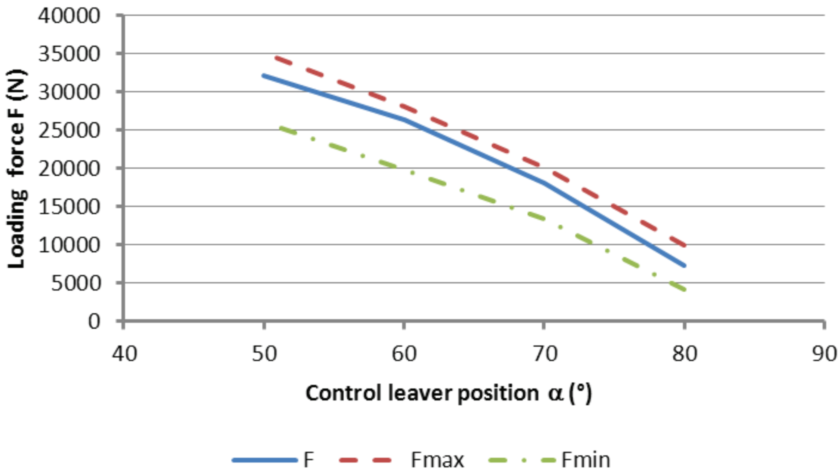
The values of static control deviation expressed as a percentage decrease with increasing values

I: *Experimental results of standard hydraulics*

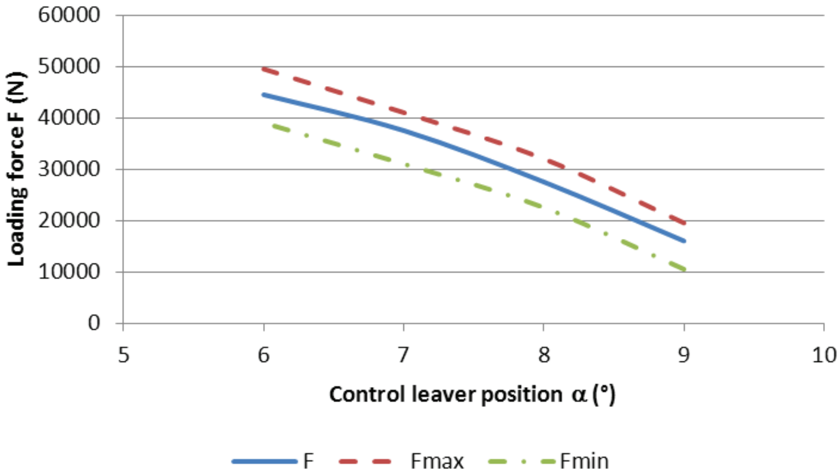
Control lever position a	Lifting arm angle f	Nominal force F	Maximal force F_{max}	Upper static control deviation ΔF		Minimal force F_{min}	Lower static control deviation ΔF	
[°]	[°]	[N]	[N]	[N]	[%]	[N]	[N]	[%]
Tractor: Z-8011		**STANDARD HYDRAULIC**				**Control: power**		
80	26	7,300	9,930	+ 2,630	36.03	4,100	–3,200	43.8
70	14	18,000	20,060	+ 2,060	11.44	13,330	–4,670	25.9
60	–1	26,300	28,030	+ 1,730	6.45	19,800	–6,500	24.2
50	–18	32,000	34,970	+ 2,970	9.28	26,030	–5,970	18.6
Tractor: Z-161 45		**STANDARD HYDRAULIC**				**Control: power**		
9	11	16,000	19,500	+ 3,500	21.9	10,500	–5,500	34.4
8	2	27,500	32,000	+ 4,500	16.4	22,500	–5,000	18.2
7	–7	37,500	41,000	+ 3,500	9.3	31,000	–6,500	17.3
6	–16	44,500	49,500	+ 5,000	11.2	39,000	–6,500	12.4

II: *Experimental results of EHR 4 BOSCH*

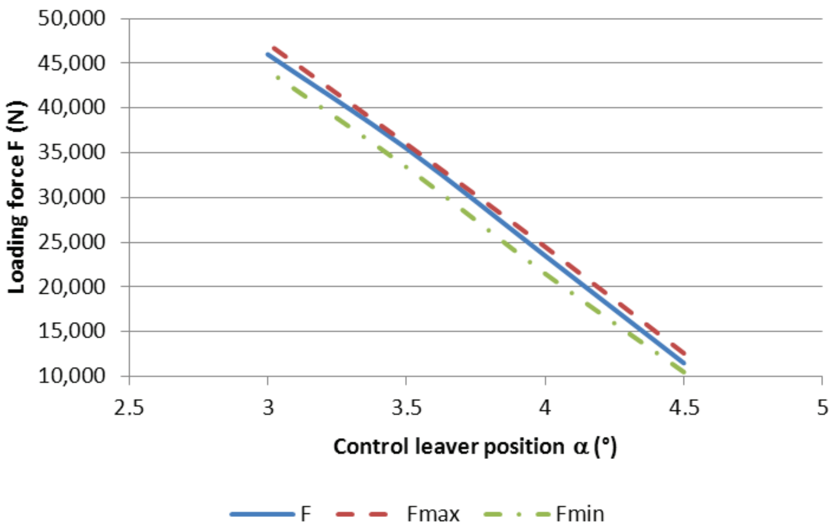
Control lever position a	Lifting arm angle f	Nominal force F	Maximal force F_{max}	Upper static control deviation ΔF		Minimal force F_{min}	Lower static control deviation ΔF	
[°]	[°]	[N]	[N]	[N]	[%]	[N]	[N]	[%]
Tractor: Z-161 45 EHR 4 BOSCH			**Control: power**			**Sensitivity: maximal**		
4.5	14	11,500	12,600	+ 1,100	9.5	10,500	–1,000	8.7
4	4	23,500	24,500	+ 1,000	4.2	21,500	–2,000	8.5
3.5	–7	35,500	36,000	+ 500	1.4	33,400	–2,100	5.9
3	–15	46,000	47,200	+ 1,200	2.6	44,200	–1,800	3.9
Tractor: Z-161 45 EHR 4 BOSCH			**Control: power**			**Sensitivity: minimal**		
4.5	14	12,100	26,500	+ 14,500	119	9,500	–2,600	21.5
4	4	23,500	35,800	+ 12,300	52.3	18,500	–5,000	21.3
3.5	–7	35,600	48,200	+ 12,600	35.4	29,400	–6,200	17.4
3	–15	45,400	59,100	+ 13,700	30.1	40,800	–4,600	10.3



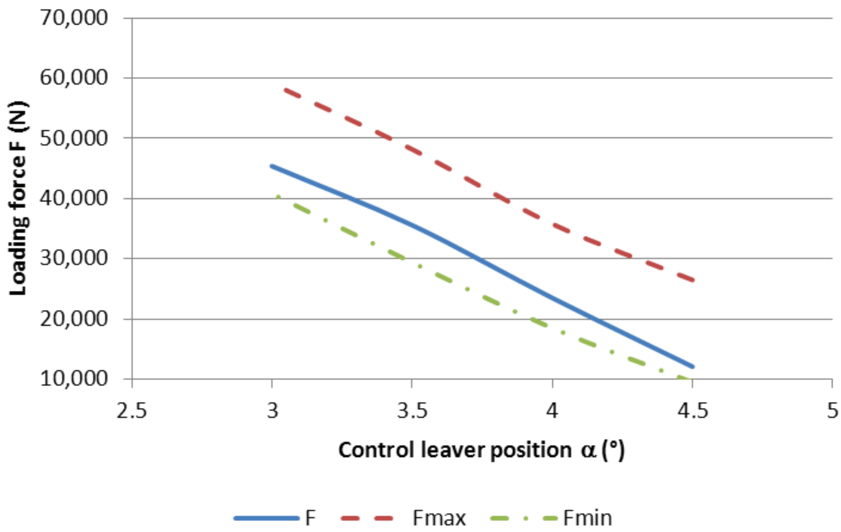
2: *Relationship between the control lever position and the loading force of the Z – 8011 tractor with mechanical hydraulic control*



3: *Relationship between the control lever position and the loading force of the Z – 16145 tractor with standard hydraulic*



4: *Relationship between the control lever position and the loading force of the Z – 16145 tractor with standard hydraulic*



5: *Relationship between the control lever position and the loading force of the Z – 16145 tractor with electro-hydraulic control EHR 4 BOSCH when set to the minimum sensitivity*

of nominal force. Simultaneously, the absolute value of static control deviation is increased or stays approximately the same. Interesting is the fact that the lower static control deviation shows higher values on both tested tractors. Values of nominal force correspond with the power category of both types of tested tractors, and for the Z-16145 tractor the position of the operating lever is indicated on the corresponding labels marked on the scale of the control panel (1 label answers to angle 7.5°).

SUMMARY

Considerably, different results were obtained for tests of the electro-hydraulic control EHR 4 BOSCH, namely on adjustment of the maximum sensitivity of the control mechanism. The obtained results presented in Tab. I and in Fig. 4 show that at the maximum sensitivity, the absolute value of static control deviation stays relatively constant in the whole control range, and in comparison with the standard hydraulics, it achieves even five times lower values. At the minimum sensitivity, the value, especially of the upper static control deviation, is considerably increased (Tab. II, Fig. 5), and it achieves higher values than the standard hydraulics.

The presented results indicate that the standard hydraulic achieves comparable parameters with the electro-hydraulic control EHR 4 BOSCH, by adjusting the minimum sensitivity.

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